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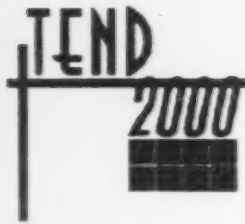
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ABSTRACT

In 1983, an entrepreneurial engineering class was developed at the University of New Mexico. The course meets for 3 hours 1 evening per week for 15 or 16 sessions. Lectures, reading assignments, group work, interactive class discussions, and presentations by practitioners are used to help learners students develop the research and practice skills needed to produce start-up business plans. The course has evolved based on student and instructor evaluations. The businesses proposed by course participants have targeted industrial, commercial, consumer, and government markets and have been based on the development and sale of products such as the following: hardware, software, systems, chemicals, biomedical products, biologicals, consulting services, and instrumentation. Class members have included engineering students (juniors and seniors), faculty, professional engineers and scientists, and retirees. Many class members have been professionals whose advanced degrees did not prepare them for entrepreneurship. Some course completers have started their own businesses or used the techniques taught in the course within larger businesses. Some businesses planned in the class have incorporated and had sales. One course participant started a company that now has offices in other countries. (An abbreviated copy of a syllabus recently used for the class is appended.) (MN)

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Crossroads of the New Millennium

Entrepreneurship Education

Prepared and Presented

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Abstract

Technical entrepreneurship has emerged in the last decades of the 20th century as an increasingly important activity. This paper asserts that entrepreneurship can be taught and uses the entrepreneurial engineering class, which the presenter developed at the University of New Mexico, as a case study of how this has been done. Two important aspects of the class are described: class structure based on six essential business "technologies" and class process where students learn by doing.

The class structure and process described in this paper not only has enabled students to start successful new technical companies, but also has allowed class graduates to enhance business success within existing companies. Class members make extensive use of computers for a range of tasks necessary to produce their startup business plans for businesses they have proposed.

Entrepreneurship Education

INTRODUCTION

The last decade of the 20th century was marked by rapid growth of new businesses due principally to innovative technological changes in a generally peaceful world. New business growth and the consequent employment growth were triggered largely by entrepreneurial efforts both in new startup entities and within larger enterprises.

The essence of entrepreneurship is evaluating and incurring risk and making decisions that maximise the likelihood of success, investing capital and time creatively and managing production and sales in hopes of success in the marketplace. Entrepreneurs need to evaluate possibilities, distinguish business opportunities from ideas, determine alternative paths for pursuing the opportunities and assess probabilities of successful introduction and growth of their innovations. Although personal aptitude for innovation is helpful, this is no guarantee of success. Peter Drucker, in his *Innovation and Entrepreneurship* made a strong case that entrepreneurship skills are learnable. The University of New Mexico College of Engineering (UNM) was among the first engineering colleges to offer an entrepreneurial engineering course.

Studies show that businesses run by persons who have taken such classes are much more likely to be successful. The writer developed the entrepreneurial engineering course in 1983 drawing on his 17 years in industry, mostly as Director of Research and Vice President, Advanced Technology, at Ampex Corporation, a leading company in the fields of information storage and retrieval, audio, video and digital.

This paper identifies entrepreneurial skills that can be taught, describes how such skills are taught, and provides a curriculum for teaching them. The paper uses the University of New Mexico School of Engineering Entrepreneurial Engineering as a case study of how these objectives can be accomplished.

The UNM Entrepreneurship Engineering class seeks to facilitate participants' learning fundamental entrepreneurial skills. It has evolved since 1983 on the basis of student and instructor evaluations. It is not a required class. It meets for three hours one evening per week for 15 or 16 sessions. By lectures, reading assignments, group work, interactive class discussions and presentations by practitioners, students learn the research and practice skills to produce their startup business plans. In the last class, class participants present their business plans orally and in written form.

To date, class businesses have targeted industrial, commercial, consumer and government markets and based their proposed companies upon products such as the following: hardware, software, systems, chemicals, biomed, biological, consulting and instrumentation. Class members have been students (junior, senior), faculty, professional engineers and scientists, even retired people. Many of the professionals have had masters and/or doctor degrees; one had an MBA and indicated that his MBA training did not prepare him to be an entrepreneur. Those completing the class have started their own businesses and employed the techniques within larger businesses.

One of the first things class participants learn is to distinguish between an idea and an opportunity and not to pursue ideas unless there is a strong likelihood that the idea will lead to a genuine business opportunity. We all tend to have frequent ideas about alternative ways of doing things; only occasionally may one conceive an idea that is a genuine business opportunity filling a vacant market niche.

An abridged class syllabus in the Appendix gives an overview of class foci. These foci and the class process are essential components of successful entrepreneurship training.

CLASS STRUCTURE

The entrepreneurship class develops student understanding of what the student knows and enhances her/his ability to find out what she/he doesn't know about the six essential business "technologies" that successful companies must use: engineering/science; production/manufacturing; marketing; finance; legal; management. These "technologies" require continually evolving skill and knowledge in areas that are critical to successful entrepreneurship. The course focuses upon students learning essential aspects of each area so they can attend to the multiplicity of factors involved in conducting successful businesses.

The professor introduces the six technologies in lectures and homework in the first three classes (evenings, once a week three hours long with a break). The introductory lecture gives the professor an opportunity to define entrepreneurship and introduce definitions of the six technologies. It is assumed that class members are sufficiently familiar with at least some aspects of engineering/science, but have only superficial familiarity with the remaining five technologies. Thus, following the entrepreneurship discussion, the focus is upon manufacturing and deals with capital equipment, facilities, total quality management, just-in-time inventories and other manufacturing elements. Assigned homework reviews the lecture topics and provides more specifics than can be provided in the class period.

The second class focuses on legal factors (including corporate organisation, regulation and intellectual property), and on marketing. Engineers in the U.S. generally have some working awareness of intellectual property laws and of marketing and sales. However, they invariably have significant misconceptions and they are not aware of much that is essential for successful entrepreneurship. We deal with different types of patents, copyrights and trademarks, national and international, as well as costs, processes, statutory bars, selection of and working with patent attorneys.

Each country has different laws and regulations that control what can and cannot be done in starting and growing a company. These laws relate to corporate structure, type of financing available, manufacturing conditions and standards, employment, product liability, environmental aspects, etc.. The extent to which the laws and regulations are enforced is highly determinative of the structure and funding of a company. Laws and regulations, as well as customs vary widely. Thus the ease/difficulty of starting a successful company varies widely among countries and even within countries.

To demystify marketing, we identify different types of markets: consumer, commercial, industrial, governmental, and different types of marketing for each. We emphasize the overwhelming necessity of identifying an available market niche. Students learn the many components of marketing from research to sales. They learn that marketing also involves product protection, costs of overhead and production/sales and the challenge of pricing that is fair to customers so that they perceive product value. Marketing needs to understand customer needs and desires, to provide service, and to set sales prices with sufficient margin to cover all direct and indirect costs and generate a healthy profit. Students learn that strong margins are an absolute necessity. Student inexperience tends to lead them to underestimate the margin that sales must produce to cover R&D costs, taxes, the inevitable errors and unexpected costs, and still leave sufficient profit. Homework includes in-depth reading assignments and a minimum of two hours identifying each of about 20 marketing references in the Business School library and learning the contents of each. The homework helps students learn where to begin doing their indirect market research.

The third class introduces students to finance and management technologies. Finance causes technical people more trouble than most of the business technologies. How to raise money, just what to charge, especially for a new product or service, are enormous challenges. It seems even more of a challenge to project future capital and expense costs with sufficient accuracy.

We require that students prepare proformas, three spreadsheets, cash flow, operating statement (profit/loss), and a balance sheet for the first five years of operation. Further, we ask for an assumption sheet listing the assumptions made in producing the proformas. Students have more difficulty doing the proforma than almost anything else. Startup managers tend to seriously underestimate the time and costs to accomplish different tasks and do not appropriately reflect these costs and times in the proformas. They tend to violate the axiom, "do not fool yourself," and let their wishes overpower their rational assessments.

A very important aspect of the finance technology is the sources and timing sequence of raising equity and expense money. Commonly, initial financing is available only from one's own and one's family's resources and thereafter some other financial investment is necessary for first and possible succeeding phases of growth. Extremely rarely may money be raised from venture capitalists. They are only going to invest if they can assess a high likelihood of being able to exit from their investment within 5-7 years with a compounded return of 40 -70% per annum return on their investment. (On the face of it, this seems high; however, perhaps a third of their investments may fail, another third give barely their investment back and the remaining third have to give sufficient returns to overcome the losses of the bottom two thirds and an acceptable return to the investors.) In some countries loans with interest are generally not available and only equity investments may be negotiated. In the US, banks are tightly regulated and will only loan on the basis of receivables or capital goods that can easily be sold for more than the debt. Further, available interest rates vary significantly over time.

It seems strange, but working engineers almost always experience some poor management and then, too often, become poor managers themselves. We focus on leadership as well as essential analytic, judgmental, creative capabilities and clear unambiguous honest communication. It has been observed that inventors know how things work and entrepreneurs know how people work. It is possible to learn effective management and leadership techniques and with practice, to incorporate these automatically. A continuing management analytic and judgmental challenge is to choose among strategic and tactical opportunities when there is insufficient available knowledge and insufficient funds to do all that the manager would like. The reading assignments give relevant case studies.

CLASS PROCESSES

A fundamental approach to the class is to recognise that the instructor's task is to facilitate learning, and that a subject such as entrepreneurship seems best learned by doing, not just

reading and hearing about the technologies. Also, we tend to learn more effectively if we have been involved. Thus, instead of assigning a hypothetical business as a class project, class members are asked to propose their own ideas for actual business startups. Students present their ideas in the first four classes, and then in the fourth class, pick those ideas in which there is the most interest. Four or five class members form a group to develop a business plan about each chosen idea. Entrepreneurial class participants learn to evaluate ideas and drop, as soon as recognised, those that do not appear to be opportunities for successful businesses.

In the fourth class, the groups select their first manager and plan their management rotation schedule through the semester. The fourth class lecture reviews what is required in a business plan and the homework readings give examples of better and weaker business plans. An important part of the homework is for all to study an actual business plan (SmartSafety Systems for the 1999 class semester, an actual beginning business plan published in the class text). Commonly, groups select days, times, location for weekly meetings. Manager tasks are to assure that each group member does his/her share of the work and fill in for others when trips require them to be out of town.

In the fifth class, half the managers are to present their groups' analyses of SmartSafety Systems as a desirable investment to the class as if the class were a panel of potential investors. The other managers, as if representing potential investors, present their groups' business plan evaluations indicating weaknesses and necessary changes if the investors are to seriously consider possible investment. Following the SmartSafety presentations, the instructor facilitates more thorough analysis of the SmartSafety plan. He gets inputs from class members and writes strong and weak aspects the class identifies on the blackboard, adding his thoughts as may be required. He then invites students to indicate by show of hands whether she/he would invest 10, 25, 50% of one's assets in the startup, first as it is written in the text business plan, and second with the class's proposed changes. Thereafter, and in subsequent classes managers use overhead projectors for their reports, and hand in their written assessments.

For homework, the groups begin serious work on their business plans and continue doing this for their homework for the rest of the semester. The groups develop their own time lines, bring them up to date weekly and begin doing their business research. The managers report their progress weekly. Class members critique these reports and give positive and negative feedback suggestions regarding the business and the presentations.

The remaining classes take place while the groups are doing the necessary research to prepare their business plans and write their first and second drafts and final business plans. This is the crucial time when most of the learning takes place. Students have to use what they learned from the previous class discussions and their homework and apply their creativity, judgement and analysis to develop frameworks for their business plans. They have to use succinct, effective communication and computer skills to develop the content of their business plans.

During this period, successful professionals working in the five business technologies, (production/manufacturing, marketing, finance, legal and management), speak to the class. Class members have to deal with difficult questions during this period. The professor has told each guest about the class businesses and about some of the current difficulties and concerns students are having. Guests share essential lessons they have learned in their fields, identify common problems startup entrepreneurs tend to have and discuss solutions and considerations relative to difficulties previously identified by the professor. Class members find these sessions very beneficial and spend as much time asking questions as the guests spend in their presentations. Often these question and answer periods last beyond class time. The professor has advised the class that the guests have agreed to consult with class members at no charge if members so request.

Experience has shown that, prior to the final written and oral business plan presentations, it is important to have two dry runs during class time. Class members and the instructor write recommendations to presenters and hand them directly to each.

LESSONS LEARNED FROM THE ENTREPRENEURIAL ENGINEERING CLASSES

Experience in the UNM Entrepreneurial Engineering class suggests that the following approaches facilitate learning:

1. Since people tend to work harder and learn more when they work on topics for which they feel some ownership, we ask students during the first three classes to propose their ideas for what they hope may become actual businesses. Usually about twelve ideas are presented. Then, in the fourth session, students vote for the ideas they would most like to work on and make selections. We want the potential businesses to be actual, not hypothetical.
2. Learning to work in a group is essential in business today. In the fourth session we divide into groups of four or five people. Each group will prepare a business plan for the idea the members have chosen. Also, to give management experience, each group rotates manage-

- ment among members. The manager's task is to balance the workload, encourage co-operative work and keep the research and business plan preparation on a timeline which, like a PERT chart, identifies each recognised task, when it is started and finished, and who is accountable for it. Students invariably underestimate the time required for these tasks and have to update their timelines weekly; each time showing what percentage of each task has been accomplished.
3. Group members are on their own. They learn how to do the kinds of things entrepreneurs must do while preparing their business plans. The professor answers questions and has office hours, but does not tell students what to do. Since, generally, students have never done indirect market research in libraries or on the web, they learn while doing.
 4. When the groups are first formed, all groups are asked to study a real startup business plan (SmartSafety Systems in 1999). Students are told to use this class business as a benchmark against which the groups are to measure their own. Students use this example for their own business plans.
 5. While groups are working on their business plans outside of class, business professionals, CEOs and venture capitalists present their own experiences to the class during class sessions. Working on their own business plans seems to motivate students to really learn from these presentations. Class evaluations always especially appreciate this phase.

CLASS RESULTS

Results of the class are anecdotal; there are no longitudinal studies. Some of the known results include:

1. Some class businesses have incorporated and had sales.
2. Some class members decided to start other businesses. For example, one business plan leader realised after the class that the business based upon the plan developed in the class would not result in a satisfactory business. He started a completely different business that became quite successful.
3. One small company had an employee join the class to develop business plan for its innovation, a portable cogeneration unit. Other class members formed a group with the employee and produced a business plan. The company began selling units in Japan. Months later, a Japanese company acquired the company.
4. Using what he learned in the class, another class graduate started a company in Khartoum which grew significantly and now has offices in other countries.
5. A successful local merchant had recognised a niche and invented and patented a potential product. Needing a business plan, his son took the class, and, with a group, produced a

business plan. The father's business now produces the product in Asia and has substantial sales.

6. Several class graduates have started successful consulting companies. For example, one well regarded businessman with 20 years experience and in a significant position in his company, decided that his life was not satisfactory. He took the class, and with a group, produced a business plan. Using that business plan he started a very successful consulting business. A few years later, he told the professor he had never been happier.
7. Undergraduate and graduate students tend to continue their degree work and not to start their businesses. Some of them have joined large companies, and using some of what they learned, were promoted more rapidly than they would have been otherwise. They report significant value applying what they have learned in their work.
8. Because of their secure research positions, PhD class graduates have tended not to start their potential new businesses, even though they sometimes already had sales. One of these turned down such a business possibility with a large first potential sale because he wanted to develop a business involving his hobby, drumming. He took the class a second time, focused upon a business relating to music and now has his business underway in Albuquerque.

APPENDIX

The following is an abbreviated copy of a recently used syllabus for the class.

UNIVERSITY OF NEW MEXICO
ENTREPRENEURIAL ENGINEERING
Spring 1999

5:30 - 8:30 PM Tuesdays beginning January 21

The objectives of the course are twofold: (1) to provide a learning and clinical experience for participants so they will be more likely to become successful technical entrepreneurs and/or to evaluate accurately the potential of new technical ventures, and (2) to launch new technical businesses. Students will work in groups of four or five and produce preliminary business plans for new ventures. The course instructional material is structured about the six basic elements, all of which must be satisfactorily accomplished for every successful technical venture:

ENGINEERING/SCIENCE, MANUFACTURING, MARKETING, FINANCE, LEGAL, AND MANAGEMENT

The focus is upon conducting those efforts, which are necessary to produce the business plan for launching a business. We want all plans, the end products of the course, to be for real startup businesses; the plans and other proprietary aspects of the class are confidential. The business plans produced in the class give details about how the company is projected to grow over a five-year period. The plans may also be used in the search for necessary financing.

Students will gain experience working with and managing a group to achieve a common objective. After completion of the course, students will be better able to identify venture opportunities, evaluate them, and if innovating a new business, more likely to succeed.

COURSE GRADING

- | | |
|---|-----|
| 1. Midterm | 20% |
| 2. Class and group participation, group management and productivity | |
| - peer evaluation | 20% |
| - Instructor evaluation | 20% |
| 3. Business plan, the same for all group members | 40% |
| (1st and 2nd drafts 10%, oral presentation, 10%, written plan 20%) | |

ME 456 CLASS CALENDAR

SPRING 1999

Meeting	Date	Topic
1	1/19	Introductory lecture: Entrepreneurship, R&D, Manufacturing
2	1/26	Introductory lecture: Legal, Marketing
3	2/2	Introductory lecture: Finance, Management
4	2/9	Business plan lecture, choice of businesses
5	2/16	Evaluation of SmartSafety Systems business plan; Manager reports
6	2/23	Lectures: Corporate legal matters; Marketing
7	3/2	Lecture: Intellectual Property legal matters; Manager reports
8	3/9	Lecture: Financing I; Manager presentations
	3/15-20	Spring Break
9	3/23	Midterm; manager presentations
10	3/30	Group meetings with venture specialists; first proforma drafts due
11	4/6	Lecture: Financing II; small business experience

12	4/13	Lecture: Leadership, Management of a growth company; Venture Capitalist
13	4/20	First draft of business plan due; first presentation dry run
14	4/27	Second draft of business plan due; second presentation dry run
15	5/4	Final business plan submittal and presentation to startup professionals

TEXTS

- Startup, W. J. Stolze, 4th Edition, Career Press, Hawthorn, NJ; *How to Really Create a Successful Business Plan*, Inc; *The Vest Pocket Entrepreneur*, Prentice Hall.

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- T. J. Peters and R. H. Waterman, Harper and Row, (1982). *In Search of Excellence*.
- Brandt, *Entrepreneuring*, New America Library, (paperback \$5.95)
- *Code of Federal Register*, 37 (Patent Law).
- *Manual of Patent Examining Procedure*, US Patent Office (about \$75).
- T. Mosley, Dover, (1992). *Marketing Your Invention*.
- N. Seitz, Reston, (1983). *Finance for Non Financial Managers*.